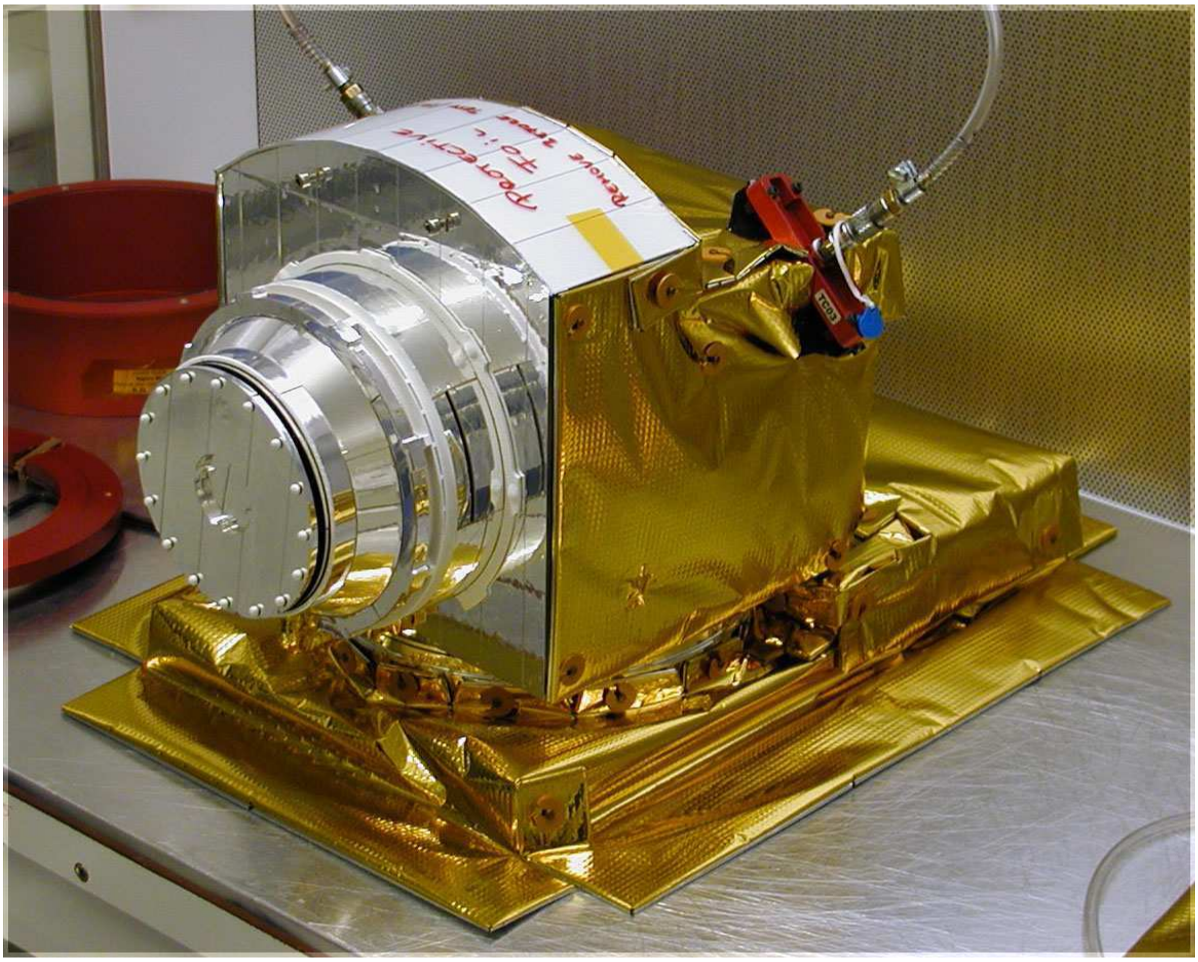
Venus Express

ASPERA-4

ELS Data Analysis Summary

v2.0

February 09, 2009



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1. ASPERA-4 Electron Spectrometer

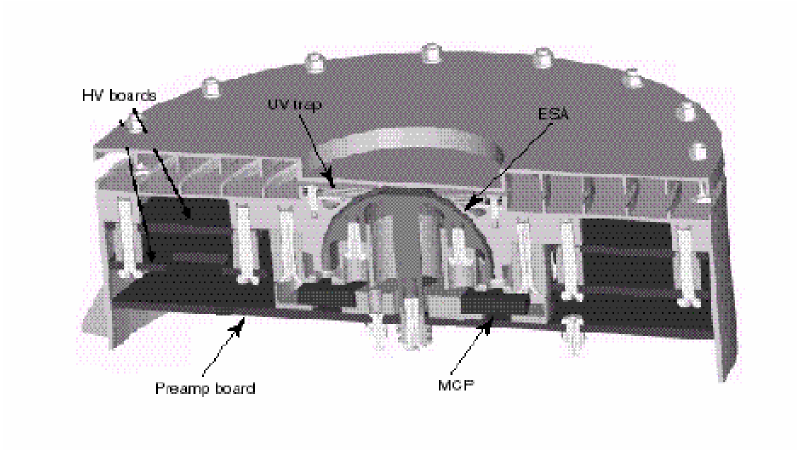

Figure 1: Cutaway diagram of ELS

The ELS instrument was manufactured by South-west Research Institute (SwRI) in San Antonio, Texas as the Flight Spare for Mars Express. It represents a new generation of ultra-light, low-power, electron sensor (Barabash et al, 2004). It is formed by a spherical top-hat electrostatic analyzer and a collimator system (Figure 1). Particles enter the aperture at any angle in the plane of incidence. Electrons are then deflected into the spectrometer by applying a positive voltage to the inner spherical electron deflection plate. The electrons hit a micro channel plate (MCP) after being filtered in energy by the analyzer plates. The plates are stepped in voltage to achieve an energy spectrum. Electrons with energies up to 20 keV/q will be measured, with a maximum time resolution of one energy sweep per four seconds. There are 16 anodes behind the MCP, each anode defining a 22.5 ° sector and each connected to a preamplifier. The ELS sensor will be mounted on the ASPERA-4 scan platform, on top of the NPI sensor, in such a way that the full 4-π angular distribution of electrons will be measured during each platform scan.

2. MSSL calibration facility

The design of MSSL's calibration facility for electron instruments is based on Marshall et al, 1986. The calibration system is housed in a cylindrical stainless steel vacuum chamber. A grounded μ-metal shroud inside the chamber, enclosed at both ends, ensures that the residual magnetic field inside the chamber is less than one tenth of the Earth's magnetic field; this results in an electron beam divergence of less than 1° at 1keV.

Light from a mercury UV lamp outside the vacuum chamber is transmitted through a quartz window on to a gold-coated quartz disc inside the chamber. Over 90% of the output wavelength of the lamp is at the 253.7nm mercury line. The energy of the incident UV light is just sufficient to knock photoelectrons out of the gold layer on the quartz disc and as a result, the kinetic energy of the ejected photoelectrons is small (~0.3eV). These electrons are then accelerated by an electric field and emerge through the grid with an energy defined by the applied voltage (between 5eV and10keV). The intensity of the beam can be varied by placing one of a series of neutral density filters in front of the UV lamp. The cross-section of the resulting electron beam is approximately 120mm in diameter.

The instrument to be calibrated is mounted on a 2-axis rotary table, which allows movement of the instrument over the complete azimuthal and elevation

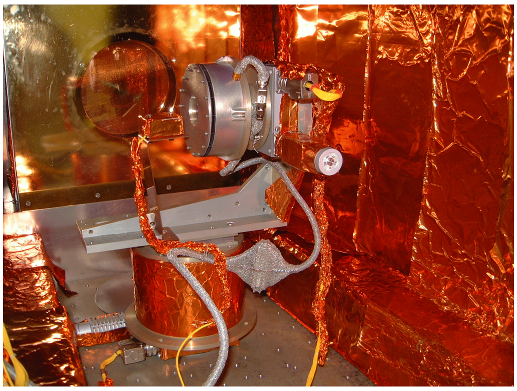

Figure 3: The Venus Express ASPERA-4 ELS sensor mounted in the MSSL calibration facility

angle response range. The mounting is such that the centre of the instrument aperture is at the centre of rotation of both the axes. This ensures that the centre of the aperture is always illuminated by the same area of the beam. A channeltron is mounted as close as possible to the instrument aperture in order to provide a constant reference to the beam intensity. A schematic diagram of the calibration facility is shown in Figure 2. A photograph of the Venus Express ASPERA-4 instrument inside the MSSL calibration facility is presented in Figure 3.

3. Energy-angle scans

All of the analyser parameters are extracted from the Energy (sweep voltage) – Angle scans carried out at the centre of each anode for beam energies of 10eV, 30 eV, 50eV, 70eV, 100eV, 200eV,1 keV, 3 keV, 6 keV, 10 keV, 12 keV. An example plot at 200 eV is shown in Figure 4.

4. K-factors

Figure 5 is a plot of the lab-measured k-factor for the 10 energies, shown as different colour lines. Table 1 shows the energy-averaged k-factors for each anode.

Table 1: Energy sensitivity for each anode (eV/V)

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10.490	10.627	10.824	10.956	11.077	11.192	11.310	11.397	11.315	11.193	11.007	10.808	10.558	10.419	10.355	10.363

A 4D polynomial fit to the values above gives the following relationship between k-factor (k) and anode (a):

$$k = 10.518 + 0.0424a + 0.0573a^2 - 0.00889\,a^3 + 0.000323\,a^4 \tag{1}$$

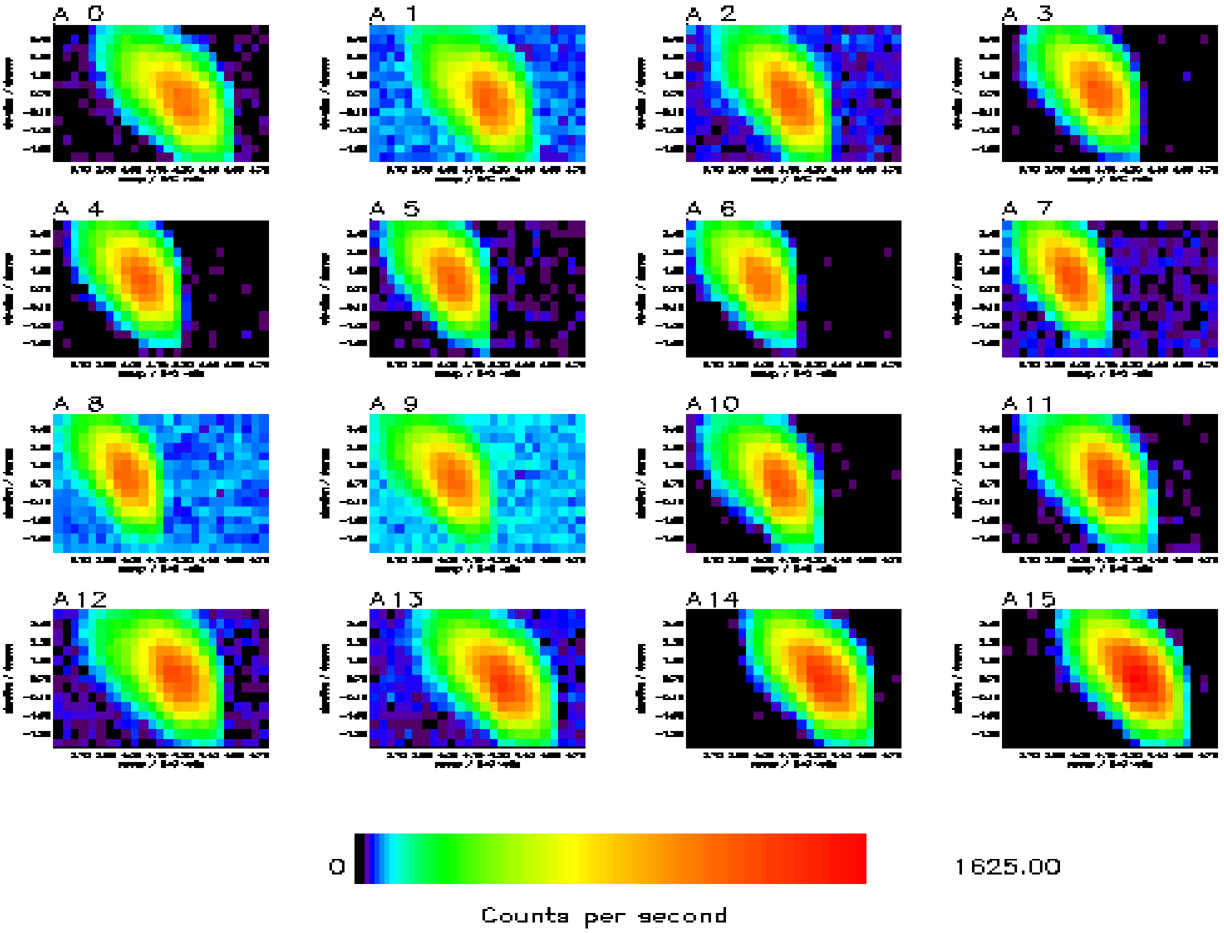

Figure 4: Energy-angle response of ELS at 200eV electron beam energy

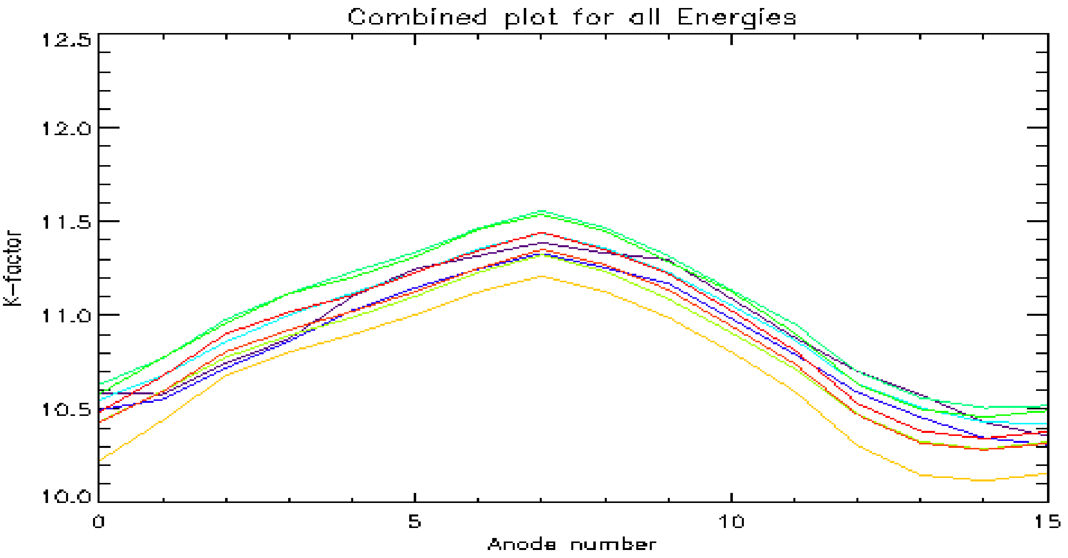

Figure 5: Plot of analyser k-factor across the 16 anodes for 10 beam energies

5. Energy Resolution

Figure 6 is a plot of the energy resolution across the 16 anodes. The measured values are given in Table 2.

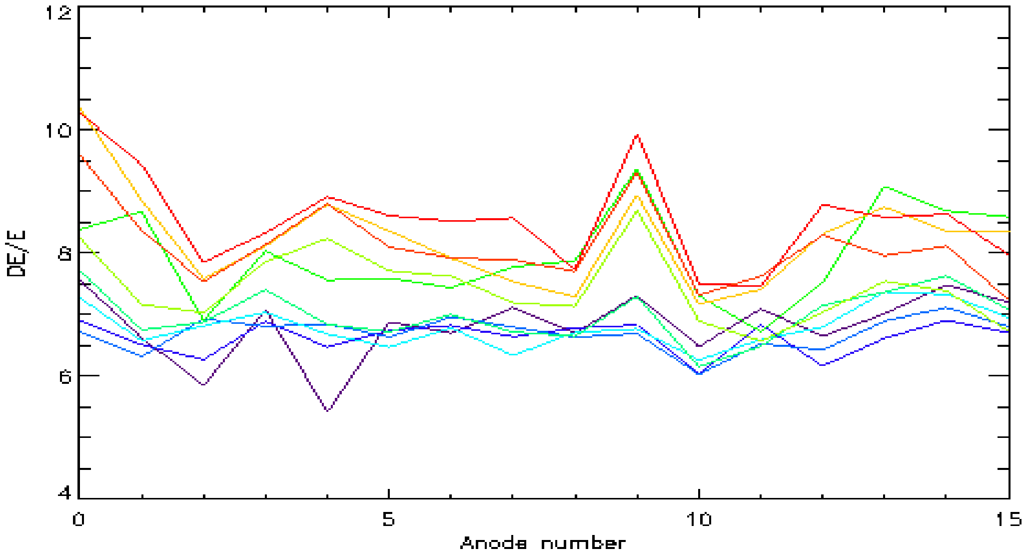

Figure 6: Plot of energy resolution across the 16 anodes for 10 beam energies

Table 2: Laboratory measured energy resolutions

Energy(eV) Anode	**29.9200**	**50.3000**	**70.2000**	**100.400**	**199.990**	**970.000**	**3021.00**	**5994.00**	**9990.00**	**11997.0**
0	7.56060	6.90909	6.72312	7.27587	7.72092	8.50001	8.24999	10.3585	9.60001	10.2789
1	6.63077	6.51376	6.31894	6.58139	6.75295	8.47059	7.16505	8.85577	8.36232	9.43137
2	5.84375	6.27102	6.93560	6.82143	6.87952	6.90908	7.03000	7.58824	7.53731	7.84849
3	7.07937	6.89624	6.81164	7.03614	7.40244	8.31249	7.85859	8.11000	8.13636	8.32654
4	5.41935	6.47620	6.85121	6.68675	6.84146	7.53125	8.23470	8.78788	8.80303	8.91752
5	6.88524	6.74758	6.63986	6.47561	6.72839	7.43750	7.71134	8.35714	8.09231	8.60825
6	6.70492	6.82524	6.96503	6.78750	7.00000	7.71875	7.62500	7.91752	7.92188	8.51579
7	7.11667	6.64357	6.80357	6.33751	6.72151	7.29032	7.18750	7.53609	7.89063	8.56842
8	6.70492	6.78431	6.63604	6.71606	6.65000	7.43750	7.13541	7.28866	7.70313	7.73958
9	7.31147	6.83496	6.69231	6.76830	7.29630	7.84376	8.69388	8.94950	9.30769	9.93815
10	6.48387	6.02885	6.03114	6.26507	6.15854	7.43750	6.89898	7.17000	7.31819	7.50000
11	7.09523	6.83962	6.52881	6.59524	6.48810	6.36364	6.57426	7.41176	7.62686	7.46000
12	6.65626	6.16667	6.42857	6.80233	7.15116	8.02941	7.03847	8.31429	8.28986	8.78640
13	7.01538	6.61817	6.89903	7.36781	7.36781	8.64707	7.54286	8.74528	7.95715	8.57693
14	7.48485	6.90991	7.11290	7.32955	7.63219	8.88235	7.38095	8.35515	8.11428	8.63460
15	7.19697	6.71171	6.81108	6.95454	7.08045	7.79412	6.73333	8.33962	7.24286	7.97116

Using the data in Table 2, we find that the energy resolution, ΔE/E, for each anode can be fit to the log of the energy (E) by the equation:

$$(2) \qquad \Delta E/E = m_0 + m_1 \log10(E)$$

The coefficients m_0 and m_1 are given for each anode in Table 3:

Table 3: Coefficients for energy resolution straight line fit

Anode	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
m_0	4.969	4.749	5.507	6.063	4.293	5.366	5.780	5.735	5.991	4.928	5.302	6.190	5.141	5.943	6.469	6.347
m_1	1.211	0.998	0.528	0.555	1.143	0.724	0.585	0.533	0.394	1.098	0.516	0.256	0.805	0.626	0.475	0.339

6. Fine polar scans

The energy-angle scans also provide the peak response of the instrument for each energy. In order to obtain the relative response of the instrument, a fine scan is carried out at polar steps of 0.25 degrees across the polar range of $\pm 168.75^0$ at the peak elevation and voltage. Figure 7 is an example of the response at 100 eV.

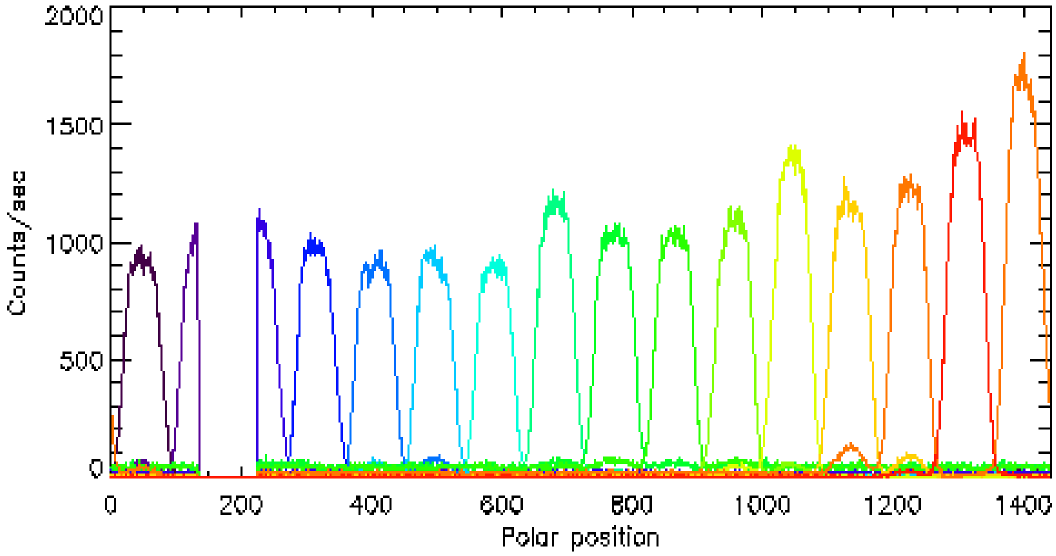

Figure 7: Plot of the analyser response at peak elevation and sweep voltage at fine polar steps in a 100eV beam

7. Energy Table

The Venus Express engineering telemetry (TM) packets include indices representing the deflection reference voltage applied to the ELS. The anode-dependent centre energies are calculated using this TM index. There are two deflection power supplies – the low range supply, which produces a voltage from 0V to 21.8V, and the high range supply which covers 0V to 2777V. For each setting, the TM packet gives the range and the index for the power supply. The index can be between 0 at 4095. If the deflection range is Low, the deflection plate voltage requested is determined by the equation:

(3) Low Range Reference Deflection Voltage [volts] = TM * (21.8 / 4095)

If the deflection range is High, the voltage requested on the deflection plates is determined by the equation:

(4) High Range Reference Deflection Voltage [volts] = TM * (2777.0 / 4095)

To convert these voltages to anode-dependent energies, they are simply multiplied by the k-factors as calculated using the anode-dependent relationship, Equation (1), given in Section 4.

Table 4 shows the centre energy values, for each anode, for the 127 energy steps most commonly used in the standard 4s resolution measurements. It also gives the TM index, and which power supply is being used. Table 5 shows the centre energy values for the 31 energy steps used in the 1s resolution measurements.

Table 4: The anode-dependent 4s energy table using the k-factors from Table 1. Energies in eV.

Power Supply	**TM Index**	**Anode/ Energy**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Low	16	**1**	0.895892	0.903655	0.917020	0.932436	0.947009	0.958508	0.965360	0.966653	0.962137	0.952219	0.937969	0.921118	0.904053	0.889825	0.882145	0.885383
Low	18	**2**	1.00788	1.01661	1.03165	1.04899	1.06539	1.07832	1.08603	1.08748	1.08240	1.07125	1.05522	1.03626	1.01706	1.00105	0.992413	0.996056
Low	19	**3**	1.06387	1.07309	1.08896	1.10727	1.12457	1.13823	1.14636	1.14790	1.14254	1.13076	1.11384	1.09383	1.07356	1.05667	1.04755	1.05139
Low	21	**4**	1.17586	1.18605	1.20359	1.22382	1.24295	1.25804	1.26703	1.26873	1.26280	1.24979	1.23108	1.20897	1.18657	1.16790	1.15782	1.16207
Low	23	**5**	1.28784	1.29900	1.31822	1.34038	1.36133	1.37786	1.38770	1.38956	1.38307	1.36881	1.34833	1.32411	1.29958	1.27912	1.26808	1.27274
Low	25	**6**	1.39983	1.41196	1.43284	1.45693	1.47970	1.49767	1.50837	1.51040	1.50334	1.48784	1.46558	1.43925	1.41258	1.39035	1.37835	1.38341
Low	27	**7**	1.51182	1.52492	1.54747	1.57349	1.59808	1.61748	1.62904	1.63123	1.62361	1.60687	1.58282	1.55439	1.52559	1.50158	1.48862	1.49408
Low	29	**8**	1.62380	1.63787	1.66210	1.69004	1.71645	1.73730	1.74971	1.75206	1.74387	1.72590	1.70007	1.66953	1.63860	1.61281	1.59889	1.60476
Low	32	**9**	1.79178	1.80731	1.83404	1.86487	1.89402	1.91702	1.93072	1.93331	1.92427	1.90444	1.87594	1.84224	1.80811	1.77965	1.76429	1.77077
Low	35	**10**	1.95976	1.97674	2.00598	2.03970	2.07158	2.09674	2.11172	2.11455	2.10467	2.08298	2.05181	2.01494	1.97762	1.94649	1.92969	1.93678
Low	38	**11**	2.12774	2.14618	2.17792	2.21454	2.24915	2.27646	2.29273	2.29580	2.28507	2.26152	2.22768	2.18765	2.14713	2.11333	2.09509	2.10279
Low	41	**12**	2.29572	2.31561	2.34986	2.38937	2.42671	2.45618	2.47373	2.47705	2.46548	2.44006	2.40355	2.36036	2.31664	2.28018	2.26050	2.26879
Low	45	**13**	2.51970	2.54153	2.57912	2.62248	2.66346	2.69580	2.71507	2.71871	2.70601	2.67812	2.63804	2.59064	2.54265	2.50263	2.48103	2.49014
Low	49	**14**	2.74367	2.76744	2.80837	2.85559	2.90022	2.93543	2.95641	2.96038	2.94654	2.91617	2.87253	2.82092	2.76866	2.72509	2.70157	2.71149
Low	53	**15**	2.96764	2.99336	3.03763	3.08869	3.13697	3.17506	3.19775	3.20204	3.18708	3.15423	3.10702	3.05120	2.99467	2.94755	2.92211	2.93283
Low	57	**16**	3.19162	3.21927	3.26688	3.32180	3.37372	3.41468	3.43909	3.44370	3.42761	3.39228	3.34152	3.28148	3.22069	3.17000	3.14264	3.15418
Low	62	**17**	3.47158	3.50166	3.55345	3.61319	3.66966	3.71422	3.74077	3.74578	3.72828	3.68985	3.63463	3.56933	3.50320	3.44807	3.41831	3.43086
Low	68	**18**	3.80754	3.84053	3.89734	3.96285	4.02479	4.07366	4.10278	4.10828	4.08908	4.04693	3.98637	3.91475	3.84222	3.78176	3.74912	3.76288
Low	74	**19**	4.14350	4.17940	4.24122	4.31252	4.37992	4.43310	4.46479	4.47077	4.44988	4.40401	4.33811	4.26017	4.18124	4.11544	4.07992	4.09490
Low	80	**20**	4.47946	4.51827	4.58510	4.66218	4.73505	4.79254	4.82680	4.83327	4.81068	4.76110	4.68985	4.60559	4.52026	4.44913	4.41073	4.42692
Low	87	**21**	4.87141	4.91362	4.98630	5.07012	5.14936	5.21189	5.24914	5.25618	5.23162	5.17769	5.10021	5.00858	4.91579	4.83842	4.79666	4.81427
Low	95	**22**	5.31936	5.36545	5.44481	5.53634	5.62287	5.69114	5.73182	5.73950	5.71269	5.65380	5.56919	5.46914	5.36781	5.28334	5.23774	5.25696
Low	103	**23**	5.76731	5.81728	5.90332	6.00256	6.09637	6.17039	6.21450	6.22283	6.19375	6.12991	6.03818	5.92969	5.81984	5.72825	5.67881	5.69965
Low	112	**24**	6.27124	6.32558	6.41914	6.52705	6.62906	6.70955	6.75752	6.76657	6.73496	6.66553	6.56579	6.44782	6.32837	6.22878	6.17501	6.19768
Low	121	**25**	6.77518	6.83389	6.93496	7.05155	7.16176	7.24872	7.30053	7.31031	7.27616	7.20116	7.09339	6.96595	6.83690	6.72930	6.67122	6.69571
Low	132	**26**	7.39	7.45	7.56	7.69	7.81	7.90	7.96	7.97	7.93	7.85	7.73	7.59	7.45	7.34	7.27	7.30

			111	515	542	260	283	769	422	489	763	581	825	922	844	106	770	441
Low	143	**27**	8.00704	8.07641	8.19587	8.33365	8.46389	8.56666	8.62790	8.63946	8.59910	8.51046	8.38310	8.23249	8.07997	7.95281	7.88417	7.91311
Low	155	**28**	8.67896	8.75415	8.88363	9.03297	9.17415	9.28554	9.35192	9.36445	9.32070	9.22462	9.08658	8.92333	8.75801	8.62018	8.54578	8.57715
Low	169	**29**	9.46286	9.54485	9.68602	9.84885	10.0028	10.1242	10.1966	10.2103	10.1626	10.0578	9.90730	9.72931	9.54906	9.39878	9.31766	9.35186
Low	183	**30**	10.2468	10.3355	10.4884	10.6647	10.8314	10.9629	11.0413	11.0561	11.0044	10.8910	10.7280	10.5353	10.3401	10.1774	10.0895	10.1266
Low	199	**31**	11.1427	11.2392	11.4054	11.5972	11.7784	11.9214	12.0067	12.0227	11.9666	11.8432	11.6660	11.4564	11.2442	11.0672	10.9717	11.0120
Low	216	**32**	12.0945	12.1993	12.3798	12.5879	12.7846	12.9399	13.0324	13.0498	12.9888	12.8550	12.6626	12.4351	12.2047	12.0126	11.9090	11.9527
Low	235	**33**	13.1584	13.2724	13.4687	13.6952	13.9092	14.0781	14.1787	14.1977	14.1314	13.9857	13.7764	13.5289	13.2783	13.0693	12.9565	13.0041
Low	255	**34**	14.2783	14.4020	14.6150	14.8607	15.0930	15.2762	15.3854	15.4060	15.3341	15.1760	14.9489	14.6803	14.4083	14.1816	14.0592	14.1108
Low	277	**35**	15.5101	15.6445	15.8759	16.1428	16.3951	16.5942	16.7128	16.7352	16.6570	16.4853	16.2386	15.9468	15.6514	15.4051	15.2721	15.3282
Low	301	**36**	16.8540	17.0000	17.2514	17.5415	17.8156	18.0319	18.1608	18.1852	18.1002	17.9136	17.6455	17.3285	17.0075	16.7398	16.5954	16.6563
Low	327	**37**	18.3098	18.4684	18.7416	19.0567	19.3545	19.5895	19.7295	19.7560	19.6637	19.4610	19.1698	18.8253	18.4766	18.1858	18.0288	18.0950
Low	355	**38**	19.8776	20.0498	20.3464	20.6884	21.0118	21.2669	21.4189	21.4476	21.3474	21.1274	20.8112	20.4373	20.0587	19.7430	19.5726	19.6444
Low	385	**39**	21.5574	21.7442	22.0658	22.4367	22.7874	23.0641	23.2290	23.2601	23.1514	22.9128	22.5699	22.1644	21.7538	21.4114	21.2266	21.3045
Low	419	**40**	23.4612	23.6645	24.0145	24.4182	24.7998	25.1009	25.2804	25.3142	25.1960	24.9362	24.5631	24.1218	23.6749	23.3023	23.1012	23.1860
Low	455	**41**	25.4769	25.6977	26.0778	26.5161	26.9306	27.2576	27.4524	27.4892	27.3608	27.0787	26.6735	26.1943	25.7090	25.3044	25.0860	25.1781
Low	494	**42**	27.6607	27.9003	28.3130	28.7890	29.2389	29.5939	29.8055	29.8454	29.7060	29.3998	28.9598	28.4395	27.9126	27.4734	27.2362	27.3362
Low	536	**43**	30.0124	30.2724	30.7202	31.2366	31.7248	32.1100	32.3396	32.3829	32.2316	31.8993	31.4220	30.8574	30.2858	29.8091	29.5519	29.6603
Low	582	**44**	32.5881	32.8704	33.3566	33.9174	34.4475	34.8657	35.1150	35.1620	34.9977	34.6370	34.1186	33.5057	32.8849	32.3674	32.0880	32.2058
Low	632	**45**	35.3877	35.6944	36.2223	36.8312	37.4069	37.8611	38.1317	38.1828	38.0044	37.6127	37.0498	36.3841	35.7101	35.1481	34.8447	34.9726
Low	687	**46**	38.4674	38.8007	39.3745	40.0365	40.6622	41.1559	41.4501	41.5057	41.3117	40.8859	40.2741	39.5505	38.8178	38.2069	37.8771	38.0161
Low	746	**47**	41.7710	42.1329	42.7561	43.4748	44.1543	44.6904	45.0099	45.0702	44.8596	44.3972	43.7328	42.9471	42.1515	41.4881	41.1300	41.2810
Low	810	**48**	45.3545	45.7475	46.4241	47.2046	47.9423	48.5245	48.8713	48.9368	48.7082	48.2061	47.4847	46.6316	45.7677	45.0474	44.6586	44.8225
Low	880	**49**	49.2741	49.7010	50.4361	51.2840	52.0855	52.7179	53.0948	53.1659	52.9175	52.3720	51.5883	50.6615	49.7229	48.9404	48.5180	48.6961
Low	955	**50**	53.4736	53.9369	54.7346	55.6548	56.5246	57.2109	57.6199	57.6971	57.4275	56.8356	55.9851	54.9792	53.9606	53.1114	52.6530	52.8463
Low	1037	**51**	58.0650	58.5681	59.4344	60.4335	61.3780	62.1233	62.5674	62.6512	62.3585	61.7157	60.7921	59.6999	58.5939	57.6718	57.1740	57.3839
Low	1127	**52**	63.1044	63.6512	64.5926	65.6785	66.7050	67.5149	67.9975	68.0886	67.7705	67.0719	66.0682	64.8812	63.6792	62.6771	62.1361	62.3642
Low	1223	**53**	68.4798	69.0731	70.0947	71.2731	72.3870	73.2659	73.7897	73.8885	73.5433	72.7853	71.6960	70.4079	69.1035	68.0160	67.4290	67.6765
Low	1329	**54**	74.4150	75.0598	76.1700	77.4505	78.6609	79.6161	80.1852	80.2926	79.9175	79.0937	77.9101	76.5103	75.0929	73.9111	73.2732	73.5421
Low	1443	**55**	80.7983	81.4984	82.7038	84.0941	85.4084	86.4454	87.0634	87.1800	86.7727	85.8783	84.5931	83.0733	81.5343	80.2511	79.5585	79.8505
Low	1567	**56**	87.7414	88.5017	89.8107	91.3204	92.7477	93.8739	94.5449	94.6716	94.2293	93.2579	91.8624	90.2119	88.5407	87.1472	86.3951	86.7122
Low	1702	**57**	95.3005	96.1263	97.5480	99.1879	100.738	101.961	102.690	102.828	102.347	101.292	99.7765	97.9839	96.1686	94.6552	93.8382	94.1826
Low	1848	**58**	103.476	104.372	105.916	107.696	109.380	110.708	111.499	111.648	111.127	109.981	108.335	106.389	104.418	102.775	101.888	102.262
Low	2007	**59**	112.378	113.352	115.029	116.962	118.790	120.233	121.092	121.255	120.688	119.444	117.657	115.543	113.402	111.617	110.654	111.060
Low	2179	**60**	122.	123.	124.	126.	128.	130.	131.	131.	131.	129.	127.	125.	123.	121.	120.	120.

			009	066	887	986	971	537	470	646	031	680	740	445	121	183	137	578
Low	2366	**61**	132.480	133.628	135.604	137.884	140.039	141.739	142.753	142.944	142.276	140.809	138.702	136.210	133.687	131.583	130.447	130.926
Low	2570	**62**	143.903	145.150	147.296	149.773	152.113	153.960	155.061	155.269	154.543	152.950	150.661	147.954	145.213	142.928	141.695	142.215
Low	2791	**63**	156.277	157.631	159.963	162.652	165.194	167.200	168.395	168.621	167.833	166.103	163.617	160.677	157.701	155.219	153.879	154.444
Low	3031	**64**	169.716	171.186	173.718	176.638	179.399	181.577	182.875	183.120	182.265	180.386	177.687	174.494	171.261	168.566	167.111	167.725
Low	3291	**65**	184.274	185.870	188.620	191.790	194.788	197.153	198.562	198.828	197.899	195.860	192.929	189.462	185.952	183.026	181.446	182.112
Low	3574	**66**	200.120	201.854	204.839	208.283	211.538	214.107	215.637	215.926	214.917	212.702	209.519	205.755	201.943	198.765	197.049	197.772
Low	3881	**67**	217.310	219.193	222.435	226.174	229.709	232.498	234.160	234.474	233.378	230.973	227.516	223.429	219.289	215.838	213.975	214.761
High	31	**68**	221.114	223.030	226.329	230.134	233.730	236.568	238.260	238.579	237.464	235.016	231.499	227.340	223.128	219.617	217.721	218.521
High	34	**69**	242.512	244.614	248.232	252.405	256.350	259.462	261.317	261.667	260.444	257.760	253.903	249.341	244.721	240.870	238.791	239.668
High	37	**70**	263.911	266.197	270.134	274.676	278.969	282.356	284.374	284.755	283.425	280.503	276.306	271.341	266.315	262.123	259.861	260.815
High	40	**71**	285.309	287.781	292.037	296.947	301.588	305.250	307.432	307.844	306.405	303.247	298.709	293.342	287.908	283.377	280.931	281.962
High	43	**72**	306.707	309.364	313.940	319.218	324.207	328.143	330.489	330.932	329.386	325.990	321.112	315.343	309.501	304.630	302.001	303.109
High	47	**73**	335.238	338.142	343.144	348.912	354.366	358.668	361.232	361.716	360.026	356.315	350.983	344.677	338.291	332.968	330.094	331.305
High	51	**74**	363.769	366.921	372.348	378.607	384.524	389.193	391.975	392.501	390.667	386.640	380.854	374.011	367.082	361.305	358.187	359.502
High	56	**75**	399.432	402.893	408.852	415.725	422.223	427.349	430.404	430.981	428.967	424.546	418.192	410.679	403.071	396.727	393.303	394.747
High	61	**76**	435.096	438.866	445.357	452.844	459.921	465.506	468.833	469.461	467.268	462.451	455.531	447.347	439.059	432.149	428.419	429.992
High	66	**77**	470.759	474.838	481.861	489.962	497.620	503.662	507.262	507.942	505.569	500.357	492.870	484.015	475.048	467.571	463.536	465.237
High	72	**78**	513.556	518.005	525.667	534.504	542.858	549.449	553.377	554.118	551.529	545.844	537.676	528.016	518.234	510.078	505.675	507.532
High	78	**79**	556.352	561.173	569.473	579.046	588.096	595.237	599.492	600.295	597.490	591.331	582.482	572.017	561.420	552.584	547.815	549.826
High	84	**80**	599.148	604.340	613.278	623.588	633.334	641.024	645.606	646.471	643.451	636.818	627.289	616.018	604.606	595.091	589.955	592.120
High	92	**81**	656.210	661.896	671.686	682.977	693.652	702.074	707.093	708.040	704.732	697.468	687.030	674.687	662.188	651.766	646.141	648.513
High	100	**82**	713.272	719.452	730.093	742.367	753.969	763.124	768.579	769.609	766.013	758.117	746.772	733.355	719.769	708.442	702.327	704.905
High	108	**83**	770.334	777.008	788.501	801.756	814.287	824.174	830.065	831.178	827.294	818.766	806.514	792.024	777.351	765.117	758.513	761.298
High	118	**84**	841.661	848.953	861.510	875.992	889.684	900.486	906.923	908.138	903.895	894.578	881.191	865.359	849.328	835.961	828.746	831.788
High	128	**85**	912.988	920.899	934.519	950.229	965.081	976.799	983.781	985.099	980.497	970.390	955.868	938.695	921.304	906.805	898.979	902.279
High	139	**86**	991.448	1000.04	1014.83	1031.89	1048.02	1060.74	1068.32	1069.76	1064.76	1053.78	1038.01	1019.36	1000.48	984.734	976.235	979.818
High	151	**87**	1077.04	1086.37	1102.44	1120.97	1138.49	1152.32	1160.55	1162.11	1156.68	1144.76	1127.63	1107.37	1086.85	1069.75	1060.51	1064.41
High	164	**88**	1169.77	1179.90	1197.35	1217.48	1236.51	1251.52	1260.47	1262.16	1256.26	1243.31	1224.71	1202.70	1180.42	1161.84	1151.82	1156.04
High	178	**89**	1269.62	1280.62	1299.57	1321.41	1342.07	1358.36	1368.07	1369.90	1363.50	1349.45	1329.25	1305.37	1281.19	1261.03	1250.14	1254.73
High	193	**90**	1376.61	1388.54	1409.08	1432.77	1455.16	1472.83	1483.36	1485.35	1478.41	1463.17	1441.27	1415.38	1389.15	1367.29	1355.49	1360.47
High	210	**91**	1497.87	1510.85	1533.20	1558.97	1583.34	1602.56	1614.02	1616.18	1608.63	1592.05	1568.22	1540.05	1511.52	1487.73	1474.89	1480.30
High	228	**92**	1626.26	1640.35	1664.61	1692.60	1719.05	1739.92	1752.36	1754.71	1746.51	1728.51	1702.64	1672.05	1641.07	1615.25	1601.31	1607.18
High	248	**93**	1768.91	1784.24	1810.63	1841.07	1869.84	1892.55	1906.08	1908.63	1899.71	1880.13	1851.99	1818.72	1785.03	1756.94	1741.77	1748.16
High	269	**94**	1918	1935	1963	1996	2028	2052	2067	2070	2060	2039	2008	1972	1936	1905	1889	1896

			.70	.33	.95	.97	.18	.80	.48	.25	.57	.33	.82	.73	.18	.71	.26	.19
High	292	**95**	2082.75	2100.80	2131.87	2167.71	2201.59	2228.32	2244.25	2247.26	2236.76	2213.70	2180.57	2141.40	2101.73	2068.65	2050.80	2058.32
High	317	**96**	2261.07	2280.66	2314.40	2353.30	2390.08	2419.10	2436.40	2439.66	2428.26	2403.23	2367.27	2324.74	2281.67	2245.76	2226.38	2234.55
High	345	**97**	2460.79	2482.11	2518.82	2561.16	2601.19	2632.78	2651.60	2655.15	2642.74	2615.50	2576.36	2530.08	2483.20	2444.12	2423.03	2431.92
High	374	**98**	2667.64	2690.75	2730.55	2776.45	2819.84	2854.08	2874.49	2878.34	2864.89	2835.36	2792.93	2742.75	2691.94	2649.57	2626.70	2636.35
High	407	**99**	2903.02	2928.17	2971.48	3021.43	3068.65	3105.91	3128.12	3132.31	3117.67	3085.54	3039.36	2984.76	2929.46	2883.36	2858.47	2868.96
High	442	**100**	3152.66	3179.98	3227.01	3281.26	3332.54	3373.01	3397.12	3401.67	3385.78	3350.88	3300.73	3241.43	3181.38	3131.31	3104.29	3115.68
High	480	**101**	3423.71	3453.37	3504.45	3563.36	3619.05	3662.99	3689.18	3694.12	3676.86	3638.96	3584.51	3520.11	3454.89	3400.52	3371.17	3383.54
High	521	**102**	3716.15	3748.35	3803.79	3867.73	3928.18	3975.88	4004.30	4009.66	3990.93	3949.79	3890.68	3820.78	3750.00	3690.98	3659.12	3672.56
High	566	**103**	4037.12	4072.10	4132.33	4201.79	4267.47	4319.28	4350.16	4355.99	4335.63	4290.94	4226.73	4150.79	4073.89	4009.78	3975.17	3989.76
High	614	**104**	4379.49	4417.44	4482.77	4558.13	4629.37	4685.58	4719.08	4725.40	4703.32	4654.84	4585.18	4502.80	4419.38	4349.83	4312.29	4328.12
High	667	**105**	4757.52	4798.75	4869.72	4951.58	5028.98	5090.04	5126.42	5133.29	5109.31	5056.64	4980.97	4891.48	4800.86	4725.31	4684.52	4701.72
High	724	**106**	5164.09	5208.83	5285.87	5374.73	5458.74	5525.02	5564.51	5571.97	5545.93	5488.77	5406.63	5309.49	5211.13	5129.12	5084.85	5103.51
High	787	**107**	5613.45	5662.09	5745.83	5842.42	5933.74	6005.79	6048.72	6056.82	6028.52	5966.38	5877.10	5771.51	5664.58	5575.44	5527.31	5547.60
High	854	**108**	6091.34	6144.12	6235.00	6339.81	6438.90	6517.08	6563.67	6572.46	6541.75	6474.32	6377.43	6262.85	6146.83	6050.09	5997.87	6019.89
High	928	**109**	6619.16	6676.52	6775.26	6889.16	6996.83	7081.79	7132.41	7141.97	7108.60	7035.33	6930.04	6805.54	6679.46	6574.34	6517.60	6541.52
High	1008	**110**	7189.78	7252.08	7359.34	7483.05	7600.01	7692.29	7747.28	7757.66	7721.41	7641.82	7527.46	7392.22	7255.27	7141.09	7079.46	7105.44
High	1094	**111**	7803.19	7870.81	7987.22	8121.49	8248.42	8348.58	8408.25	8419.52	8380.18	8293.80	8169.69	8022.91	7874.27	7750.35	7683.46	7711.66
High	1188	**112**	8473.67	8547.09	8673.51	8819.31	8957.15	9065.91	9130.72	9142.95	9100.23	9006.43	8871.65	8712.26	8550.86	8416.29	8343.65	8374.27
High	1291	**113**	9208.34	9288.13	9425.50	9583.95	9733.74	9851.93	9922.36	9935.65	9889.23	9787.29	9640.83	9467.62	9292.22	9145.98	9067.04	9100.33
High	1402	**114**	10000.1	10086.7	10235.9	10408.0	10570.6	10699.0	10775.5	10789.9	10739.5	10628.8	10469.7	10281.6	10091.2	9932.35	9846.63	9882.77
High	1522	**115**	10856.0	10950.1	11112.0	11298.8	11475.4	11614.7	11697.8	11713.4	11658.7	11538.5	11365.9	11161.7	10954.9	10782.5	10689.4	10728.7
High	1653	**116**	11790.4	11892.5	12068.4	12271.3	12463.1	12614.4	12704.6	12721.6	12662.2	12531.7	12344.1	12122.4	11897.8	11710.5	11609.5	11652.1
High	1795	**117**	12803.2	12914.2	13105.2	13325.5	13533.7	13698.1	13796.0	13814.5	13749.9	13608.2	13404.6	13163.7	12919.9	12716.5	12606.8	12653.0
High	1949	**118**	13901.7	14022.1	14229.5	14468.7	14694.9	14873.3	14979.6	14999.7	14929.6	14775.7	14554.6	14293.1	14028.3	13807.5	13688.4	13738.6
High	2117	**119**	15100.0	15230.8	15456.1	15715.9	15961.5	16155.3	16270.8	16292.6	16216.5	16049.3	15809.2	15525.1	15237.5	14997.7	14868.3	14922.8
High	2299	**120**	16398.1	16540.2	16784.8	17067.0	17333.8	17544.2	17669.6	17693.3	17610.6	17429.1	17168.3	16859.8	16547.5	16287.1	16146.5	16205.8
High	2496	**121**	17803.3	17957.5	18223.1	18529.5	18819.1	19047.6	19183.7	19209.4	19119.7	18922.6	18639.4	18304.6	17965.4	17682.7	17530.1	17594.4
High	2711	**122**	19336.8	19504.3	19792.8	20125.6	20440.1	20688.3	20836.2	20864.1	20766.6	20552.6	20245.0	19881.3	19512.9	19205.9	19040.1	19110.0
High	2944	**123**	20998.7	21180.7	21493.9	21855.3	22196.9	22466.4	22627.0	22657.3	22551.4	22319.0	21985.0	21590.0	21190.0	20856.5	20676.5	20752.4
High	3197	**124**	22803.3	23000.9	23341.1	23733.5	24104.4	24397.1	24571.5	24604.4	24489.4	24237.0	23874.3	23445.4	23011.0	22648.9	22453.4	22535.8
High	3472	**125**	24764.8	24979.4	25348.8	25775.0	26177.8	26495.7	26685.1	26720.8	26596.0	26321.8	25927.9	25462.1	24990.4	24597.1	24384.8	24474.3
High	3770	**126**	26890.4	27123.3	27524.5	27987.2	28424.6	28769.8	28975.4	29014.3	28878.7	28581.0	28153.3	27647.5	27135.3	26708.2	26477.7	26574.9
High	4095	**127**	29208.5	29461.6	29897.3	30399.9	30875.0	31249.9	31473.3	31515.5	31368.2	31044.9	30580.3	30030.9	29474.5	29010.7	28760.3	28865.9

Table 5: The anode-dependent 1s energy table using the k-factors from Table 1. Energies in eV.

Power Supply	TM Index	Anode/ Energy	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Low	151	**1**	8.45498	8.52824	8.65438	8.79986	8.93740	9.04592	9.11058	9.12279	9.08016	8.98657	8.85209	8.69305	8.53200	8.39773	8.32524	8.35580
Low	168	**2**	9.40687	9.48837	9.62871	9.79058	9.94360	10.0643	10.1363	10.1499	10.1024	9.99830	9.84868	9.67174	9.49255	9.34316	9.26252	9.29653
Low	188	**3**	10.5267	10.6179	10.7750	10.9561	11.1274	11.2625	11.3430	11.3582	11.3051	11.1886	11.0211	10.8231	10.6226	10.4554	10.3652	10.4033
Low	209	**4**	11.7026	11.8040	11.9786	12.1799	12.3703	12.5205	12.6100	12.6269	12.5679	12.4384	12.2522	12.0321	11.8092	11.6233	11.5230	11.5653
Low	234	**5**	13.1024	13.2159	13.4114	13.6369	13.8500	14.0182	14.1184	14.1373	14.0712	13.9262	13.7178	13.4713	13.2218	13.0137	12.9014	12.9487
Low	261	**6**	14.6142	14.7409	14.9589	15.2104	15.4481	15.6357	15.7474	15.7685	15.6949	15.5331	15.3006	15.0257	14.7474	14.5153	14.3900	14.4428
Low	291	**7**	16.2940	16.4352	16.6783	16.9587	17.2237	17.4329	17.5575	17.5810	17.4989	17.3185	17.0593	16.7528	16.4425	16.1837	16.0440	16.1029
Low	325	**8**	18.1978	18.3555	18.6270	18.9401	19.2361	19.4697	19.6089	19.6351	19.5434	19.3420	19.0525	18.7102	18.3636	18.0746	17.9186	17.9843
Low	363	**9**	20.3256	20.5017	20.8049	21.1546	21.4853	21.7461	21.9016	21.9309	21.8285	21.6035	21.2802	20.8979	20.5107	20.1879	20.0137	20.0871
Low	406	**10**	22.7333	22.9302	23.2694	23.6606	24.0304	24.3221	24.4960	24.5288	24.4142	24.1626	23.8010	23.3734	22.9403	22.5793	22.3844	22.4666
Low	453	**11**	25.3649	25.5847	25.9631	26.3996	26.8122	27.1378	27.3317	27.3684	27.2405	26.9597	26.5563	26.0791	25.5960	25.1932	24.9757	25.0674
Low	505	**12**	28.2766	28.5216	28.9434	29.4300	29.8900	30.2529	30.4692	30.5100	30.3674	30.0544	29.6047	29.0728	28.5342	28.0851	27.8427	27.9449
Low	564	**13**	31.5802	31.8538	32.3250	32.8684	33.3821	33.7874	34.0289	34.0745	33.9153	33.5657	33.0634	32.4694	31.8679	31.3663	31.0956	31.2098
Low	630	**14**	35.2758	35.5814	36.1077	36.7147	37.2885	37.7412	38.0110	38.0620	37.8841	37.4936	36.9325	36.2690	35.5971	35.0369	34.7345	34.8620
Low	703	**15**	39.3633	39.7043	40.2916	40.9689	41.6092	42.1144	42.4155	42.4723	42.2739	41.8381	41.2120	40.4716	39.7218	39.0967	38.7593	38.9015
Low	785	**16**	43.9547	44.3356	44.9913	45.7476	46.4626	47.0268	47.3630	47.4264	47.2048	46.7183	46.0191	45.1923	44.3551	43.6570	43.2802	43.4391
Low	877	**17**	49.1061	49.5316	50.2642	51.1091	51.9080	52.5382	52.9138	52.9847	52.7371	52.1935	51.4125	50.4888	49.5534	48.7735	48.3526	48.5301
Low	979	**18**	54.8174	55.2924	56.1102	57.0534	57.9451	58.6487	59.0679	59.1471	58.8707	58.2639	57.3920	56.3609	55.3167	54.4462	53.9762	54.1744
Low	1092	**19**	61.1446	61.6744	62.5866	63.6388	64.6334	65.4182	65.8858	65.9741	65.6658	64.9890	64.0164	62.8663	61.7016	60.7306	60.2064	60.4274
Low	1220	**20**	68.3118	68.9037	69.9228	71.0982	72.2094	73.0862	73.6087	73.7073	73.3629	72.6067	71.5202	70.2352	68.9340	67.8492	67.2636	67.5105
Low	1362	**21**	76.2628	76.9236	78.0613	79.3736	80.6142	81.5930	82.1762	82.2863	81.9019	81.0576	79.8447	78.4101	76.9575	75.7464	75.0926	75.3682
Low	1520	**22**	85.1097	85.8472	87.1169	88.5814	89.9659	91.0582	91.7092	91.8320	91.4030	90.4608	89.1071	87.5062	85.8850	84.5334	83.8038	84.1114
Low	1697	**23**	95.0206	95.8439	97.2615	98.8965	100.442	101.662	102.388	102.526	102.047	100.995	99.4834	97.6960	95.8861	94.3771	93.5625	93.9060
Low	1895	**24**	106.107	107.027	108.610	110.435	112.161	113.523	114.335	114.488	113.953	112.778	111.091	109.095	107.074	105.389	104.479	104.863
Low	2115	**25**	118.426	119.452	121.219	123.256	125.183	126.703	127.608	127.779	127.182	125.871	123.988	121.760	119.504	117.624	116.609	117.037
Low	2361	**26**	132.200	133.346	135.318	137.593	139.743	141.440	142.451	142.642	141.975	140.512	138.409	135.922	133.404	131.305	130.172	130.649
Low	2636	**27**	147.598	148.877	151.079	153.619	156.020	157.914	159.043	159.256	158.512	156.878	154.530	151.754	148.943	146.599	145.333	145.867
Low	2943	**28**	164.788	166.216	168.674	171.510	174.191	176.306	177.566	177.804	176.973	175.149	172.528	169.428	166.289	163.672	162.260	162.855
Low	3286	**29**	183.994	185.588	188.333	191.499	194.492	196.854	198.261	198.526	197.599	195.562	192.635	189.175	185.670	182.748	181.171	181.836
Low	3668	**30**	205.383	207.163	210.227	213.761	217.102	219.738	221.309	221.605	220.570	218.296	215.030	211.166	207.254	203.992	202.232	202.974
Low	4095	**31**	229.292	231.279	234.700	238.645	242.375	245.318	247.072	247.403	246.247	243.709	240.062	235.749	231.381	227.740	225.774	226.603

8. Geometric Factors

The geometric factor, [GF], in units of cm^2 sr eV/eV, is given by

$$[GF] = ((e\, \Delta E\, \Delta\theta\, \Delta\phi) / (E * T_C))\, \Sigma_l\, \Sigma_m\, \Sigma_n\, N_{lmn} / I_{lmn} \tag{5}$$

where: ΔE = Spacing between calibration points in energy,
$\Delta\theta$ = Elevation spacing,
$\Delta\phi$ = Azimuth spacing,
E = Peak transmitted energy,
T_C=Accumulation time,
I=Beam current in ELS aperture per unit area,
N=ELS counts.

The geometric factors measured in the laboratory by Dhiren Kataria are displayed in Table 6. Note that [GF] incorporates both the purely geometric response of the instrument as well as the detector response.

Table 6: Laboratory measured geometric factors (cm^2 sr eV/eV)

Energy(eV) Anode	**29.9200**	**50.3000**	**70.2000**	**100.400**	**199.990**	**970.000**	**3021.00**	**5994.00**	**9990.00**	**11997.0**
0	2.07540e-006	3.37581e-006	4.73706e-006	6.46449e-006	8.85756e-006	1.08817e-005	8.04262e-006	6.94579e-006	7.42996e-006	5.75665e-006
1	4.57159e-006	5.38168e-006	6.13679e-006	7.10438e-006	9.63588e-006	1.07470e-005	8.32344e-006	7.52185e-006	8.14427e-006	6.11427e-006
2	5.28905e-006	5.95252e-006	6.63087e-006	7.39277e-006	9.47093e-006	9.99465e-006	8.43561e-006	7.54510e-006	7.78974e-006	5.80410e-006
3	4.10182e-006	5.07612e-006	5.80111e-006	6.61061e-006	8.70769e-006	9.52572e-006	8.44829e-006	7.37566e-006	7.42463e-006	5.69616e-006
4	2.75657e-006	4.23158e-006	5.19947e-006	6.14290e-006	8.25067e-006	9.26740e-006	8.10313e-006	6.92202e-006	7.06366e-006	5.36508e-006
5	3.12045e-006	4.36811e-006	5.26247e-006	6.23110e-006	8.07105e-006	8.73019e-006	7.78427e-006	6.40499e-006	6.59983e-006	4.99699e-006
6	3.43856e-006	4.15704e-006	4.80389e-006	5.51189e-006	7.23690e-006	8.07841e-006	7.01710e-006	5.74396e-006	5.92093e-006	4.49043e-006
7	4.06785e-006	4.84366e-006	5.58990e-006	6.32900e-006	8.70944e-006	9.17226e-006	7.42745e-006	5.87616e-006	6.33978e-006	4.69977e-006
8	4.72466e-006	5.15194e-006	5.69955e-006	6.96500e-006	8.51592e-006	9.72213e-006	8.29093e-006	6.61914e-006	7.63213e-006	5.41397e-006
9	4.02959e-006	4.66755e-006	5.74074e-006	7.58045e-006	9.39149e-006	1.06782e-005	9.33263e-006	6.99206e-006	8.69915e-006	5.86279e-006
10	3.20888e-006	4.50439e-006	5.59275e-006	6.49422e-006	8.33294e-006	9.62592e-006	8.62126e-006	6.89954e-006	7.48176e-006	5.68084e-006
11	4.42217e-006	5.77331e-006	6.97938e-006	8.04752e-006	1.03845e-005	1.12857e-005	9.49013e-006	6.46349e-006	8.06194e-006	6.10723e-006
12	3.76111e-006	5.24365e-006	6.59177e-006	8.00591e-006	1.04415e-005	1.29351e-005	1.00476e-005	9.05845e-006	9.09767e-006	7.05230e-006
13	4.43609e-006	5.74996e-006	7.16811e-006	8.55046e-006	1.14662e-005	1.42535e-005	1.07045e-005	9.34059e-006	9.74682e-006	7.63039e-006
14	5.90117e-006	6.89419e-006	8.37360e-006	9.65106e-006	1.17197e-005	1.44310e-005	1.06524e-005	8.89006e-006	9.61936e-006	7.42696e-006
15	6.32660e-006	7.43104e-006	9.01837e-006	1.05006e-005	1.37654e-005	1.49384e-005	1.04071e-005	8.82440e-006	9.39500e-006	7.23438e-006

To find the geometric factor for each of the energies in Table 4, we need to extrapolate from the values in Table 6. The data measured between 199.99 and 5994.00eV in Table 4 are the most reliable, therefore we only use those in the extrapolation. The best fit is found if we perform the interpolation in log-log space.

9. Calculating Raw Data from Telemetry

Due to the compression of the science values, the way in which the science data decodes is a bit complicated. First we need to figure out the science data structure and we need to decompress the data.

There are five quantities which are important when reconstructing the science data matrix. The first important quantity is the Rice Compression bit. When the Rice compression bit is set, the science data is Rice compressed. In order to be decoded, the science values within the ELS science data packet must be Rice decoded. This must happen before any decoding of the packet. Use the IRF Rice decode software to Rice decode the science data within the packet. If the Rice compression bit is not set, then the science data is not Rice compressed. Rice coding is a lossless data compression scheme to conserve the number of bits in the Venus Express mass memory.

The second important information is the sector mask. The sector mask tells you which ELS anodes are returning data within the packet. The data order is from anode 0 to anode 15 with each bit of the sensor mask representing the presence of anode data for that anode. The number of bits that are set in the sector mask tells you how many and which anodes have sweeps within the packet.

The third important information is the Log compression bit. This tells you whether the words within the packet are 8-bit or 16-bit. 16-bit words are not log compressed and the log ompression bit is set to 0. 8-bit words are log compressed and the log compression bit is set. The 8-bit output value is split in a 4-bit exponent (e) and a 4-bit mantissa (m) according to the formula:
For e<2, counts=m (for counts <= 32, the output value is the same as the input value)
For e>=2, counts=(m+16)*2^(e-1)
The compression of telemetry to 8-bits is a lossy process.

The fourth important information is the energy compression. This tells you how many energy steps are in the sweep. If the value of the energy compression is 0, there are 128 energy steps in the sweep. If the value of the energy compression is 1, there are 64 energy steps in the sweep and each science value represents the sum of two energy step values. If the value of the energy compression is 2, there are 32 energy steps in the sweep and each science value represents the sum of four energy step values. Energy compression occurs between successive energy steps obtained from the deflection values decoded from the ELS engineering data packet. Science values for each energy step are adjusted by dividing the science value by the number of energy steps included within a single science measurement.

The fifth important information is the time compression. This tells you how many sweeps are added together, forming each data value. This information is not relevant to decoding the science data, only in determining the actual value of the science data. The science values are adjusted by dividing the science value by the number of sweeps included in the sum representing a single science measurement. For example, if the time compression is a 3, representing 8 sweeps, divide all of the science values by 8. The Accumulation time for each energy step is now 28125e-6 sec and there is a latency between accumulations of 3125e-6 sec.

The index indicating time compression was to be an indicator of the number of energy sweeps included with in the sum. However, the Main Unit software does not include the science sweep within the sum if during that accumulation period of the sweeps, the Main Unit outputs an ELS engineering packet. However, it still reports the time compression as if it added the sweep. Thus, unless there is an ELS engineering packet output during the accumulation cycle, the time compression decodes as follows: TM value 0 = 1 spectra in sum, TM value 1 = 2 spectra in sum, TM value 2 = 4 spectra in sum, TM value 3 = 8 spectra in sum, TM value 4 = 16 spectra in sum. When the Main Unit outputs an engineering packet, it discards the science data for the same time period. Thus, the time compression decodes as follows: TM value 0 = 1 spectra in sum, TM value 1 = 1 spectra in sum, TM value 2 = 3 spectra in sum, TM value 3 = 7 spectra in sum, TM value 4 = 15 spectra in sum.

To convert the 16-bit science data value to absolute units, you divide each science value by the number of summed energy step values and divide by the number of sweeps included within the measurement. Expand out the science values to each of the energy steps represented in the ELS engineering data packet (for example, if a 64 step sweep, steps 0 and 1 get the same value, 2 and 3 are the same, etc.). This gives you the number of counts within an ELS accumulation for each of the 128 energy step values.

Now, throw out the last step and any steps which include the last step (for example, in a 64 step sweep, then steps 126 and 127 should be discarded). Since the last step is the flyback step, the science data is not valid and should not be included in the spectrum.

10. Data Calibration

The raw data from the telemetry is in units of counts/accumulation. The accumulation time for the Aspera-3 and 4 ELS is 3.6/128 s. So to convert to counts/second we divide the raw data by the accumulation time:

(6) Counts/sec = raw/accutime

The differential energy flux (DEF), differential number flux (DNF) and the phase space density (PSD) are all dependent on the geometric factor (GF) and the energy level (en), and thus on the anode (an).

(7) $\mathrm{DEF(an,en)}\ [\mathrm{cm}^{-2}\ \mathrm{sr}^{-1}\ \mathrm{s}^{-1}] = \mathrm{raw}/(\mathrm{GF(an,en)} \times \mathrm{accutime} \times A_A)$

(8) $\mathrm{DNF(an,en)}\ [\mathrm{cm}^{-2}\ \mathrm{sr}^{-1}\ \mathrm{s}^{-1}\ \mathrm{J}^{-1}] = \mathrm{DEF}/(\mathrm{earray(an,en)} \times E)$

(9) $\mathrm{PSD(an,en)}\ [\mathrm{cm}^{-6}\ \mathrm{s}^{3}] = (\mathrm{raw} \times m_e^{2})/(\mathrm{GF(an,en)} \times \mathrm{accutime} \times 2 \times (\mathrm{earray(an,en)} \times E)^{2} \times A_A)$

In the above equations, earray is the array that contains all the data in Table 4 or 5, E is the conversion from eV to Joules = 1.602×10^{-19} J, m_e is the mass of an electron = 9.11×10^{-31} kg, and A_A is the active anode area ratio (the proportion of the anode area that actually measures counts) = 0.87.

11. MCP voltage response

This set of tests determined the operational regime of the microchannel plate detector. Tests were carried out with the beam incident on anode 10 and the MCP voltage was raised from 1800V to 2880V. The results for the different energies, normalised to the voltage at 2,580V are shown in Figure 8.

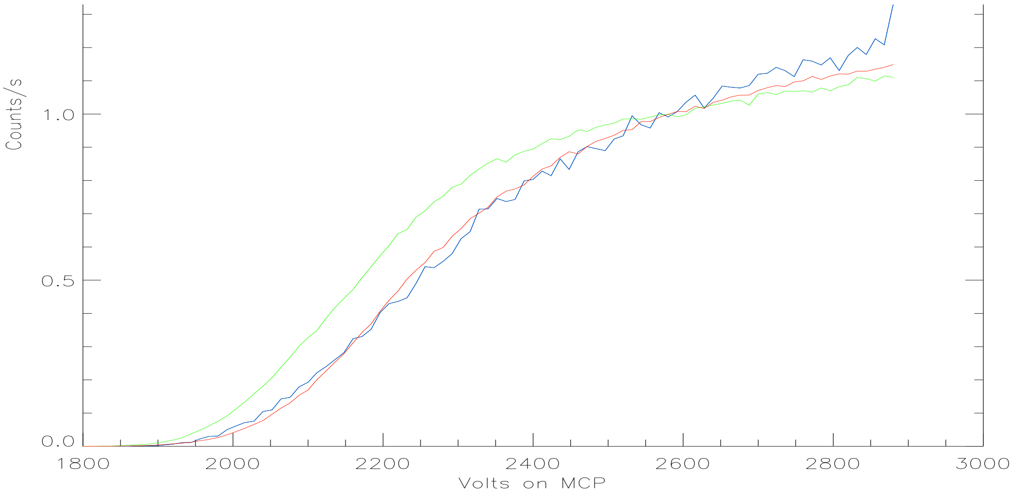

Figure 8: MCP voltage versus normalised counts at 3 energies (30eV: blue, 300eV: green & 10keV: red)

12. UV response

The response of the instrument to UV light has been studied by irradiation of a Krypton UV lamp on the entrance aperture (Alsop et al, 1998). Figure 9 shows the energy angle response of the 16 anodes to UV with the lamp facing Anode 1. As can be seen, most of the counts are observed at very low energies and are primarily due to low energy secondary electrons emitted by the incident light and eventually striking the MCP.

13. Anode selection

Anodes 5-12 have unobstructed views. Anodes 11 and 12 provide the best views and are the most commonly used in data analysis.

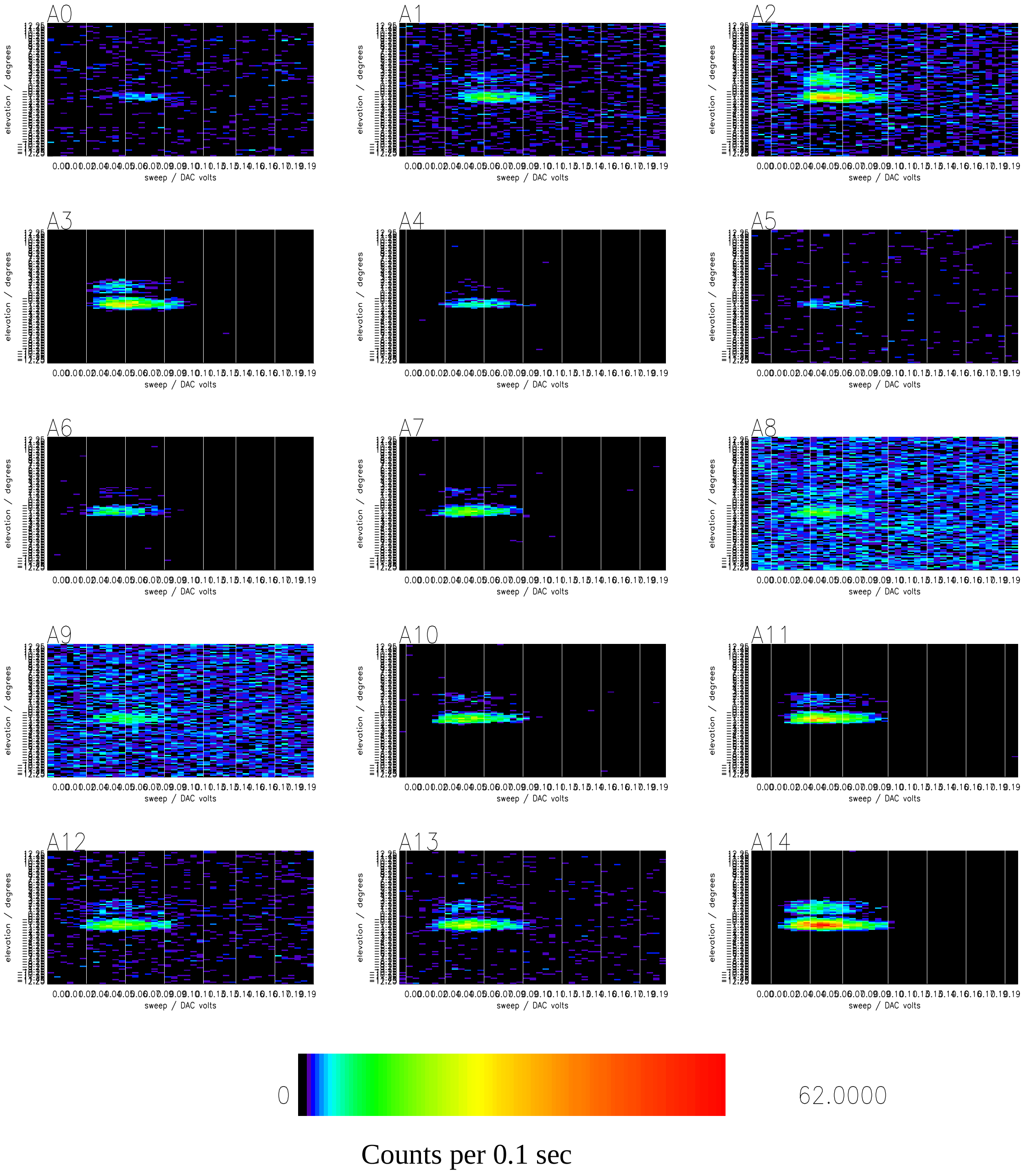

Figure 9: Energy-angle scans for UV response measurement test

14. References

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